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Intake
R4-NC-Brunswick

Brunswick Steam Electric Plant

CP&L

1998 Environmental Monitoring Report

Environmental Services Section

BRUNSWICK STEAM ELECTRIC PLANT
1998 BIOLOGICAL MONITORING REPORT

Prepared by:

Environmental Services Section

CAROLINA POWER & LIGHT COMPANY

New Hill, North Carolina

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Preface

This copy of the report is not a controlled document as detailed in the *Environmental Services Section Biology Program Procedures Manual and Quality Assurance Manual.* Any changes made to the original of this report subsequent to the date of issuance can be obtained from:

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Metric-English Conversion and Units of Measure

Length

1 micron (μm) = 4.0 x 10^{-5} inch
1 millimeter (mm) = 0.001 m = 0.04 inch
1 centimeter (cm) = 10 mm = 0.4 inch
1 meter (m) = 100 cm = 3.28 feet
1 kilometer (km) = 1000 m = 0.62 mile

Volume

1 milliliter (ml) = 0.034 fluid ounce
1 liter = 1000 ml = 0.26 gallon
1 cubic meter = 35.3 cubic feet

Area

1 square meter (m^2) = 10.76 square feet
1 hectare (ha) = 10,000 m^2 = 2.47 acres

Weight

1 microgram (μg) = 10^{-3} mg or 10^{-6} g = 3.5 x 10^{-8} ounce
1 milligram (mg) = 3.5 x 10^{-5} ounce
1 gram (g) = 1000 mg = 0.035 ounce
1 kilogram (kg) = 1000 g = 2.2 pounds
1 metric ton = 1000 kg = 1.1 tons
1 kg/hectare = 0.89 pound/acre

Temperature

Degrees Celsius (°C) = 5/9 (°F-32)

Common and Scientific Names of Species Used in This Report

Atlantic stingray	*Dasyatis sabina*
Shrimp eel	*Ophichthus gomesi*
Atlantic menhaden	*Brevoortia tyrannus*
Anchovies	*Anchoa* spp.
Bay anchovy	*A. mitchilli*
Silversides	*Atherinidae*
Atlantic silversides	*Menidia menidia*
Spotted Hake	*Urophysis regius*
Pinfish	*Lagodon rhomboides*
Silver perch	*Bairdiella chrysura*
Weakfish	*Cynoscion regalis*
Spot	*Leiostomus xanthurus*
Star drum	*Stellifer lanceolatus*
Croaker	*Micropogonias undulatus*
Gobies	*Gobiosoma* spp.
Gobies	*Gobionellus* spp.
Atlantic cutlassfish	*Trichiurus lepturus*
Southern flounder	*Paralichthys lethostigma*
Tonguefish	*Symphurus spp.*
Blackcheek tonguefish	*S. plagiusa*
Shrimp	*Penaeus* spp.
Brown shrimp	*P. aztecus*
Pink shrimp	*P. duorarum*
White shrimp	*P. setiferus*
Hardback shrimp	Trachypenaeus spp.
Swimming crab larvae	Portunid megalops
Swimming crabs	Portunidae ($\leq$ 10 mm)
Blue crabs	*Callinectes* spp.
Blue crab	*C. sapidus*
Lesser blue crab	*C. similis*

Executive Summary

Biological monitoring of the Cape Fear Estuary (CFE) at Carolina Power & Light Company's (CP&L) Brunswick Steam Electric Plant (BSEP) was conducted in 1998 as part of the National Pollutant Discharge Elimination System (NPDES) permit requirements. Monitoring results from 1998 were compared to those of previous years. Entrainment and impingement studies monitored the effectiveness of the intake modifications in reducing entrainment and impingement of fish and shellfish.

Entrainment and larval impingement comparisons indicated that utilization of fine-mesh screens reduced entrainment of larvae by approximately 7% to 58% depending upon the species present, season, and the number of coarse-mesh screens operating. Entrainment of commercial species was reduced 13% to 58%. In addition to reducing the total number of organisms entrained, use of fine-mesh screens also reduced the number of taxa entrained. Of the 51 larval taxa impinged, only 40 taxa were entrained. Without the use of fine-mesh screens, all 51 taxa would have been entrained. Goby (*Gobiosoma* spp.) was the dominant larval organism entrained whereas the dominant larva impinged was shrimp (*Penaeus* spp.) This difference in species composition between entrainment and larval impingement sampling was a result of fine-mesh screens and the relative difference in screening efficiency for these taxa. This difference is important considering that *Penaeus* spp. larvae are the commercially important shrimp species.

The dominant juvenile and adult organisms impinged were white shrimp and bay anchovy. Prior to the completion of the fish diversion structure, the dominant juvenile and adult organism impinged was Atlantic menhaden. Impingement data showed that nine out of eleven taxa (including total organisms) of juvenile and adult fish and shellfish exhibited significant decreases in impingement densities and a shift toward impingement of smaller individuals as a result of the installation of the fish diversion structure. A reduction in the impingement of larger individuals is important since these are the reproducing members of the population.

The overall survival estimate for all larvae returned to the estuary was 34% during 1998 (excluding Anchoa spp. $\geq$ 13 mm). This value decreased from 1997 due to a decrease in the number of larval crabs (portunid megalops) impinged. Portunid megalops, a taxa exhibiting excellent survival, dominated the larval samples in 1997. The reduction in the number of portunid megalops was related to the occurrence of hurricane Bonnie in late August which is normally the peak period of abundance for this taxa. Survival estimates for the larvae of the most valuable commercial species, shrimp and blue crabs, ranged from 80% to 90% depending on taxa and screen rotation speed. The survival estimate for all juvenile and adult species combined was 76% (excluding bay anchovy). This was an increase from 1997 and resulted from a substantial increase in the number of impinged juvenile and adult shrimp. As with larvae, juvenile and adult shrimp and crabs exhibited the highest survival rates.

Biological monitoring during 1998 continued to show that the combination of the diversion structure, fine-mesh screens, and the fish return system effectively reduced the number of entrained and impinged fish and shellfish. These modifications also continued to ensure that the most valuable commercial species are returned alive to the estuary in large numbers.

1.0 INTRODUCTION

Carolina Power & Light Company was issued a permit in December 1974 to discharge cooling water from the BSEP into the Atlantic Ocean under a NPDES permit. Cooling water is withdrawn from the Cape Fear River (CFR). As a stipulation of the NPDES permit, biological monitoring is required to provide sufficient information for a continuing assessment of power plant impacts on the marine and estuarine fisheries of the CFE. Data are reported annually and will provide an assessment of the effectiveness of the fish diversion structure and fine-mesh screens in minimizing the entrainment and impingement of organisms.

A stipulation of the renewed 1981 NPDES permit and subsequent permits was the implementation of power plant modifications to reduce entrainment and impingement of estuarine organisms resulting from the intake of cooling water. A permanent diversion structure was constructed across the mouth of the intake canal in November 1982 to reduce impingement by preventing large fish and shellfish from entering the intake canal (Figure 1.1). To reduce entrainment, fine-mesh (1-mm) screens were installed on two of the four intake traveling screen assemblies of each unit in July 1983 and a third was installed on each unit in April 1987. Presently three of the four intake traveling-screen assemblies on each unit are covered with fine mesh screens.

Under the current permit, a maximum intake flow of 26.1 cubic meters per second (cms) per unit is allowed from December through March, and 31.1 cms per unit is allowed from April through November. Normally only fine-mesh screens are used during these periods of maximum intake flow. The flow of one unit may be increased to 34.8 cms during July, August, and September by using a fourth intake pump operating with coarse-mesh (9.4-mm) screens.

Beginning in 1994, Carolina Power & Light Company reduced the biological monitoring program with the concurrence of the North Carolina Department of Environment & Natural Resources. Based on almost two decades of operation with no adverse impact on fish and shellfish populations in the CFE, the monitoring program was modified to concentrate on the impingement and entrainment of organisms (Figure 1.2). This report presents 1998 data on impingement and entrainment rates of larval, juvenile, and adult fish and shellfish and evaluates the effectiveness of the NPDES-required plant intake modifications.

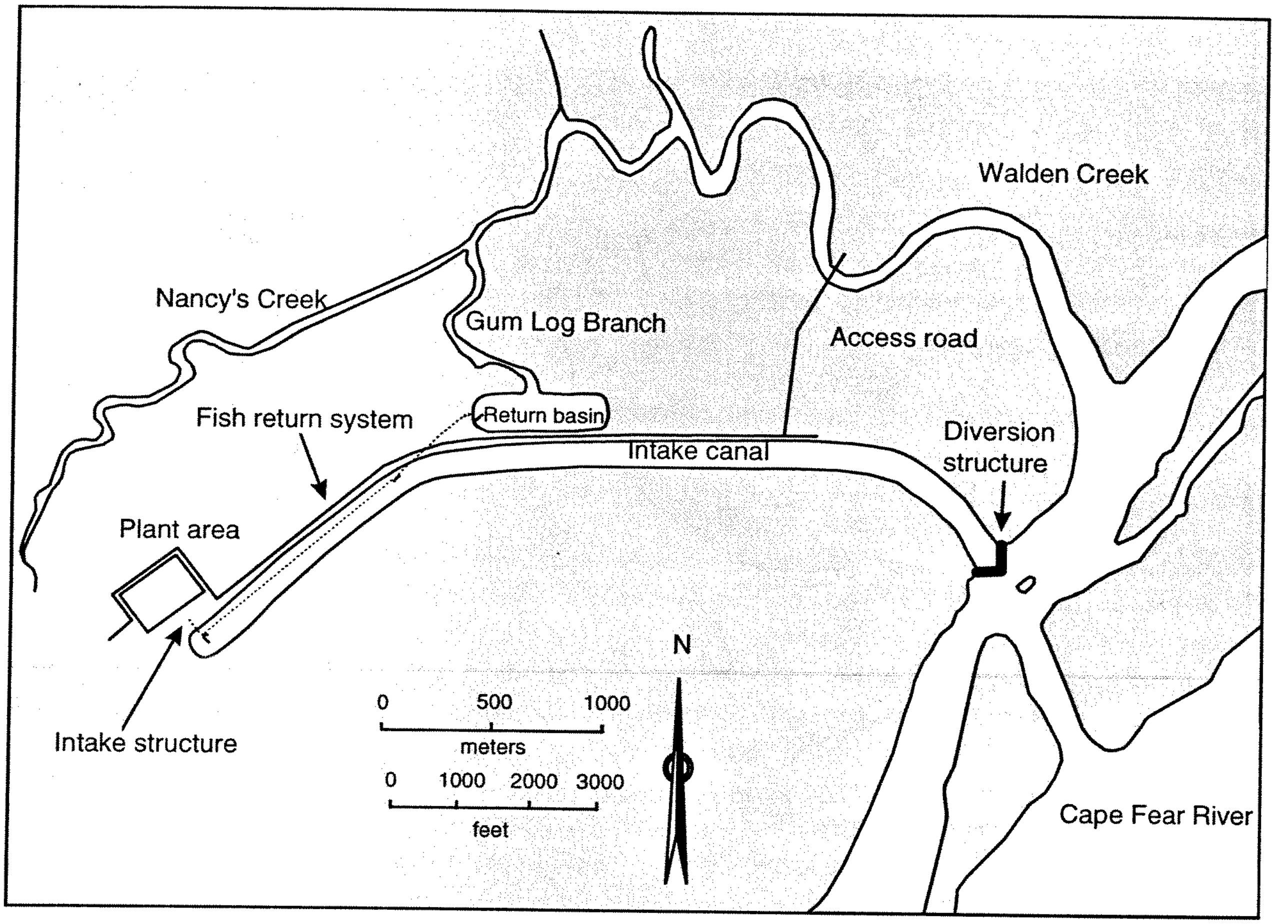

Figure 1.1 **Location of fish diversion structure, fish return system, and return basin at the BSEP.**

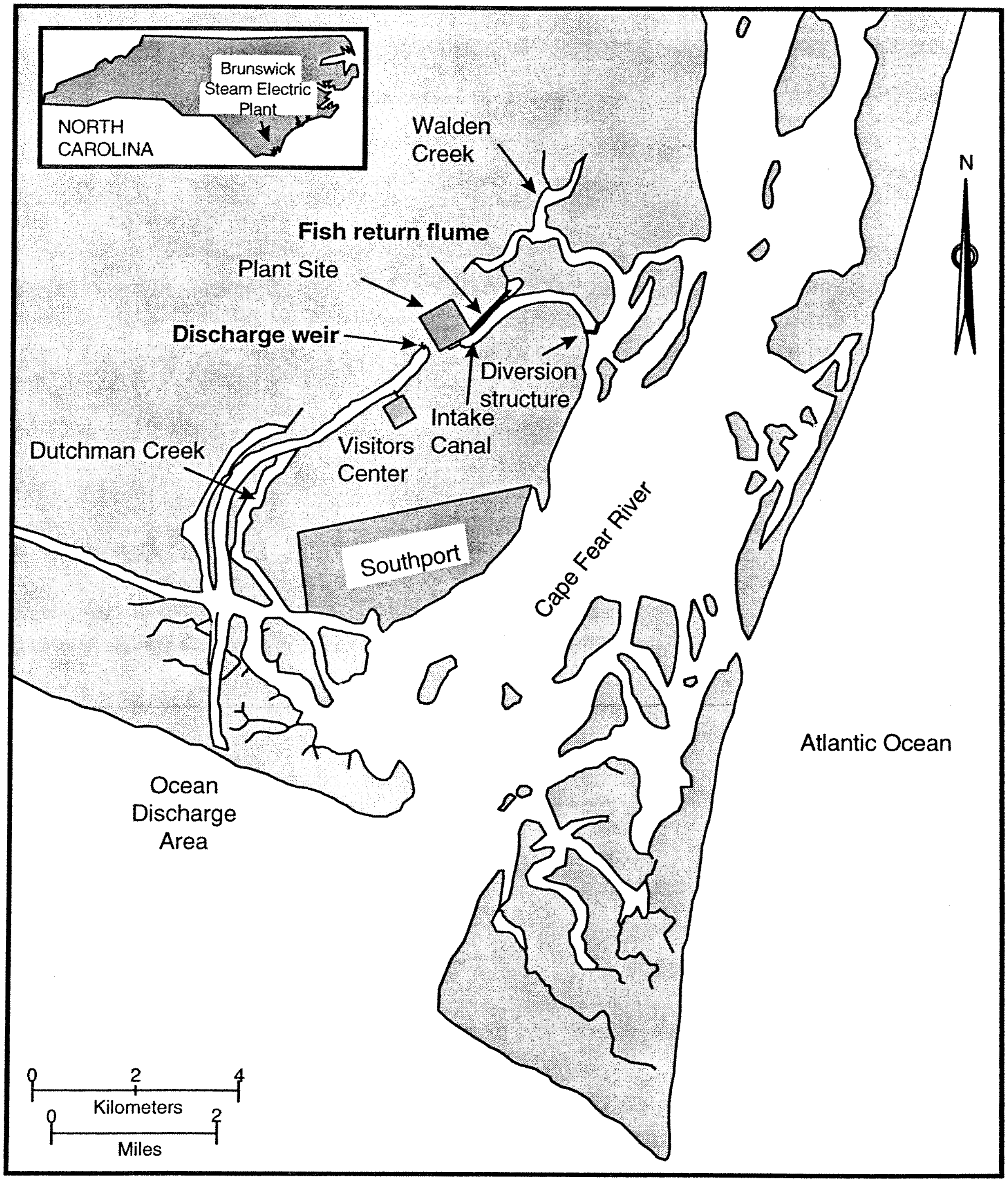

Figure 1.2 **Impingement (fish return flume) and entrainment (discharge weir) sampling locations at the BSEP for 1998.**

2.0 MONITORING PROGRAM RESULTS

2.1 Introduction

Past data indicated that the impingement of large fish and shellfish of the CFE has been reduced as a result of the 9.4-mm mesh screening on the diversion structure (CP&L 1984, 1985a, 1985b). Organisms small enough to enter the intake canal through the diversion structure may be impinged on the plant intake screens and returned to the CFE via a fish-return flume or they may be entrained through the plant. Previous studies by CP&L have documented a reduction in the entrainment of small organisms due to installation of fine-mesh screens at the intake structure and the subsequent survival of a percentage of impinged larvae returned to the CFE via the fish-return flume (Hogarth and Nichols 1981; CP&L 1989).

Entrainment sampling during 1998 documented the species composition, seasonality, and abundances of larval and postlarval organisms passing through the cooling system. Larval impingement sampling evaluated the success of the fine-mesh screens in reducing entrainment of these organisms. Juvenile and adult (J/A) impingement sampling documented species composition, densities, weights, and sizes of juvenile and adult organisms impinged during 1998 and provided evidence of the continued effectiveness of the diversion structure. Survival study results from previous years were used to determine the effectiveness of the return system at returning impinged organisms alive to the CFE (CP&L 1988).

2.2 Methods

The collection gear for entrainment and impingement has remained unchanged since 1984 (CP&L 1985a). Because sampling was conducted only once per month since 1990, results were not expanded to obtain annual estimates of organisms entrained or impinged; rather, entrainment and impingement rates, densities, and total number of organisms collected were expanded to give an estimate for 24 hours. The juvenile and adult impingement program included fish and shrimp ≥ 41 mm, portunid crabs ≥ 25 mm, and eels and pipefish ≥ 101 mm. Individuals smaller than these limits were included in the larval impingement program.

The densities calculated for all larval organisms from samples collected per sampling date were averaged to obtain a mean number per 1000 m^3 of water entrained through the plant. Densities for juvenile and adult organisms impinged on each sampling date were calculated by dividing the total number of organisms collected by the volume of water pumped through the plant. Densities were expressed as the number per million cubic meters of water pumped through the plant during each 24-hour sampling period.

Time-series analysis (ln [density + 1]) (CP&L 1985a) was performed on juvenile and adult impingement data from January 1977 through December 1998. Selected species included bay anchovy, Atlantic menhaden, croaker, spot, weakfish, southern flounder, brown shrimp, pink shrimp, white shrimp, and blue crabs (*Callinectes* spp.). The 1983 data were excluded from the analysis because impingement samples were not collected during July through December of that year. One sampling trip per month was used for all years for comparable sampling effort.

2.3 Results and Discussion

2.3.1 Dominant Species

As during previous years, *Gobiosoma* spp. was the most abundant taxa collected in entrainment samples during 1998 and comprised 28.2% of the cumulative density of all organisms collected (Table 2.1). Croaker (17.3%) was the second most abundant followed by spot and *Penaeus spp.* (9.9% and 9.1%, respectively). Other taxa entrained (in decreasing order of abundance) were Anchoa spp ($\geq$ 13 mm), portunid megalops, weakfish, *Anchoa spp.* (<13 mm), *Gobionellus spp.*, and silversides. Minor taxa comprised an additional 7.0% of the total number of organisms collected. The cumulative density of total organisms collected in entrainment samples was approximately 72.5 % greater than that collected during 1997.

The total number of organisms collected in larval impingement samples also increased approximately 70.0% from the 10 million collected in 1997 (Table 2.2; CP&L 1998). Ten taxa accounted for 95.8% of the total larval organisms collected in impingement samples during 1998. *Penaeus* spp. (20.6%) was the most dominant taxa collected. Although the relative ranking has varied, the ten most abundant species have generally dominated larval impingement samples each year since 1984. The number of larval taxa collected in impingement samples was consistently greater than the number collected in entrainment samples (Figure 2.1). Thus, use of fine-mesh screens reduced the number of taxa entrained by the plant's main cooling-water system.

Ten taxa accounted for 96.5% of the total number of organisms collected in J/A impingement samples during 1998 (Table 2.3). White shrimp was the most numerous species impinged accounting for 56.3% of the total number impinged during 1998. Bay anchovy was the second most abundant taxa impinged, accounting for 28.4% of the total number collected. Prior to intake modifications in 1983, Atlantic menhaden numerically dominated J/A impingement (CP&L 1980a, 1980b, 1982, 1983). Spot, Atlantic menhaden, lesser blue crab, blue crab, brown shrimp, star drum, croaker, and blackcheek tonguefish combined accounted for an additional 12.0% of the total number collected. These ten most abundant taxa comprised 90.4% of the total weight collected during impingement sampling. Other taxa that contributed significantly to the biomass collected during J/A impingement sampling were spotted hake (9.7 kg), Atlantic stingray (9.4 kg), southern flounder (7.9 kg), pinfish (6.8 kg), and star drum (5.9 kg). The total number of organisms collected in J/A impingement samples decreased in 1998 compared to the number in 1997 (Table 2.3; CP&L 1998).

2.3.2 Seasonality and Abundance

The seasonality for the larvae of selected species entrained in 1998 was similar to those observed in previous years and corresponded to the seasonalities of larval fish in the estuary (Tables 2.4 and 2.5; CP&L 1994). Peaks of abundance in entrainment and impingement of organisms can be influenced by operating screens without fine mesh, increasing or decreasing the flow of cooling water as determined by plant operational needs, and/or sampling period.

The typical winter and summer periods of abundance observed during 1998 in the entrainment program were also observed in the larval impingement program (Table 2.6). Atlantic menhaden, spot, croaker, and pinfish--all ocean-spawned species--were abundant during the winter and spring months. Brown shrimp was most abundant during the spring. During the late spring and summer, ocean-spawned species (such as pink and white shrimp, weakfish and hardback shrimp) and estuarine-spawned species (such as anchovy, *Gobiosoma* spp., and silversides) were abundant. The periods of maximum abundance for portunid megalops and swimming crabs (portunid crabs $\leq$ 10 mm carapace width), occurred during the spring and summer. Traditionally portunid megalops has been most abundant in the late summer and early fall rather than the spring and summer. The relatively low numbers of portunid megalops collected in late summer and early fall was most likely the result of hurricane Bonnie moving through the area during the last week of August. Mean intake canal salinity recorded during larval impingement sampling dropped from 30 ppt in August to 4 ppt the first week in September indicating intensive estuarine flushing due to hurricane Bonnie. *Gobionellus* spp. was abundant during the summer, fall, and winter.

Results from J/A impingement sampling indicated two major periods of abundance for Atlantic menhaden, spot, and croaker (Table 2.7). Atlantic menhaden, spot and croaker that were abundant during the winter and spring were yearlings from 70 mm to 130 mm long that may have overwintered in the intake canal since there were relatively few damaged diversion screens (Tables 2.7 and 2.8). Previous studies have indicated that the intake canal is used as nursery habitat by many species (Copeland et al. 1974, 1979; Birkhead et al. 1979). Peak densities of Atlantic menhaden, spot and croaker during May and June were associated with the recruitment of young-of-year individuals too small to be excluded by the diversion structure as evidenced by the small modal lengths of fish collected during those months. This pattern of abundance is consistent with previous years.

Bay anchovy was most abundant during January (Table 2.7). The peak densities of white, brown, and pink shrimp occurred during the summer and fall. Blue crab was abundant during the spring and summer. The large number of white shrimp collected during September was a result of the combination of hurricane Bonnie and an opening in the diversion structure. A seating bracket failed allowing the diversion screens to fall out of the number 9 bay on the north side of the structure. Hurricane Bonnie moved through the area during this same time period. The intensive rainfall and resulting decrease in salinity caused white shrimp to become more active. The diversion screen was replaced during the week of September 16 and the numbers of organisms impinged declined to expected levels by the following sampling trip in October (Table 2.7).

Installation of the diversion structure has resulted in a decline in the impingement densities of most J/A organisms. Results of time-series analysis indicated that total organisms and nine of the ten selected taxa exhibited significant decreases in impingement density over the past 22 years (Table 2.9). Atlantic menhaden exhibited the greatest decline in impingement density (Figure 2.2). White shrimp was the only species which exhibited a significant increase in density over the study period (Table 2.9 and Figure 2.3). The trend was a result of a natural increase in white shrimp populations in the Cape Fear Estuary. Previous studies have shown that significant increases in the white shrimp population in Walden Creek coincide with increases in impingement of this species (CP&L 1994). Postlarval shrimp too small to be excluded by the diversion structure successfully recruited to the intake canal and used it as nursery habitat and were subsequently impinged (Birkhead et al. 1979; Copeland et al. 1979; CP&L 1991). The relatively large number of white shrimp collected during September was not of sufficient magnitude to increase the overall annual mean density impinged (Figure 2.3). The annual mean density impinged for 1998 was within the range of results seen since 1991.

2.3.3 Flow Rates

The amount of water pumped through the plant can affect the number and weight of organisms impinged and entrained. Monthly intake flow volumes during 1998 ranged from 101 million m^3 in May to 169 million m^3 in August (Figure 2.4). The mean monthly flow volume during 1998 was higher than the mean flows of previous years including the period 1977-1982 when there were less stringent flow-minimization requirements. The greater monthly volumes during 1998 were a result of the significantly reduced time required for outages resulting in more continuous plant operation. The low monthly volume during May was a result of the Unit 1 refueling outage.

2.3.4 Fine-Mesh Screens

In 1998, entrainment and larval impingement rates were summed to find the total number of larvae affected. The percent effectiveness (how successfully the organisms were kept from being entrained) of fine-mesh screens was calculated as the ratio between the larval impingement rate and the total number (entrainment plus larval impingement) affected for each sampling trip. The overall effectiveness for total organisms ranged from 7% to 58% when data from all sampling trips were analyzed (Table 2.10). Previous studies have shown that the operation of three fine-mesh screens per unit versus no fine-mesh screens may reduce the total mean density of entrained organisms by 61% (CP&L 1989).

The variability of effectiveness was influenced by species composition, seasonality, organism size, and number of non fine-mesh screens operating. During January-April and October-December when fine-mesh screen efficiencies were highest, no coarse-mesh screens were operating and the dominant larvae were croaker, spot, Atlantic menhaden, *Anchoa* spp. ($\geq$13 mm), *Penaeus* spp. and portunid megalops, (taxa exhibiting relatively high fine-mesh screen efficiency) (Tables 2.5 and 2.6). Conversely, *Gobiosoma* spp. , *Anchoa* spp. ($\leq$ 13 mm), and weakfish (taxa exhibiting relatively poor fine-mesh screen efficiency) dominated the larval taxa entrained and impinged during May and June (Tables 2.5 and 2.6). This reduced the overall fine-mesh screen efficiencies for May and June (Table 2.10). The larvae of these taxa can be characterized as small (< 7 mm) and cylindrical. Body size and shape has been shown to have an effect on screening efficiency for other species of larval fish (Tomljanovich et al. 1978; Stone & Webster Engineering Corporation 1984). The lowest fine-mesh screen efficiencies for the year were recorded during July through September when one or more coarse-mesh screens were operating (Table 2.10). On July 21, the plant experienced multiple cooling water intake pump trips due to excessive detritus buildup on the fine-mesh traveling screens. As a result, with the concurrence of the North Carolina Department of Natural Resources, 50% of the fine-mesh screen panels were removed from two traveling screens on each unit (four traveling screens total). Fine-mesh traveling screens were restored to the normal configuration in October.

Larvae of the commercially important taxa (portunid megalops, *Penaeus* spp., spot, croaker Atlantic menhaden, weakfish, swimming crabs) demonstrated higher fine-mesh screen efficiencies than the larvae of noncommercial taxa (Anchovies, *Gobionellus* spp., *Gobiosoma* spp., silversides, hardback shrimp, and pinfish). Monthly fine-mesh screen efficiencies for larvae of the commercial taxa ranged from 13% to 66% (Figure 2.5). However, fine-mesh screen efficiencies for larvae of the noncommercial taxa ranged from 2% to 50%.

2.3.5 Survival Estimates

Survival was determined for selected size classes of the dominant organisms that have been impinged at the BSEP in past years (CP&L 1985a, 1986, 1987, 1988). Screens were operated on slow-screen rotation speed (75 cm/min) for most sampling dates in 1998 except for the months of June through August and November. During the June through August and November, the traveling screens were operated in fast-screen rotation speed (187-200 cm/min) due to excessive detrital buildup on the traveling screens. Survival calculations were calculated using survival rates determined during previous studies for slow-screen and fast-screen rotation (CP&L 1988). A mortality rate of 100% is used for taxa that have never been tested. Thus, the estimated survival rate for total organisms is a conservative and minimum estimate.

Nine taxa of the dominant larvae impinged were previously tested for survival on both slow and fast screen rotation speed (Table 2.11). These nine taxa accounted for about 82.4% of the total larval impingement catch. Survival during slow-screen rotation ranged from 0% for Atlantic menhaden to 86.3% for portunid megalops. Survival was greater during fast-screen rotation and ranged from 90.3% for *Penaeus* spp. to 3.2% for Atlantic menhaden. *Anchoa* spp. (≥ 13 mm), which were not considered commercially or recreationally important, were not included in the total survival estimate. Estimates indicated that approximately 33.9% of the larval species impinged, excluding *Anchoa* spp. (≥ 13 mm), were returned to the estuary alive. The overall larval survival rate decreased from 1997 (61.2%) due to the decrease in the number of portunid megalops impinged during 1998.

Eleven taxa of the dominant J/A organisms impinged were previously tested for survival on both slow-screen and fast-screen rotation (Table 2.12). These taxa accounted for 96.3% of the total number collected and 98.2% of the total weight collected. Excluding bay anchovy, survival during slow-screen rotation ranged from 53.1% for croaker to 92.1% for blue crabs. Survival during fast screen rotation speed ranged from 15.6% for Atlantic menhaden to 96.2% for blue crabs. The most valuable commercial species (shrimp and blue crabs) exhibited the highest survival rates for both screen rotation speeds. Survival estimates indicated that 76.2% of the total number and 64.2% of the total weight of the selected J/A organisms impinged, excluding bay anchovy, were returned alive to the estuary during 1998. These percentages are higher than reported for 1997 (34.1% and 36.2%, respectively) due to the increase in the number and weight of larger J/A penaeid shrimp and blue crabs impinged in 1998 (Table 2.3; CP&L 1998).

2.4 Summary and Conclusions

Seasonality of organisms collected in the 1998 entrainment and larval impingement studies were similar to previous years and corresponded to the seasonalities of larval organisms in the estuary. *Gobiosoma* spp. was the most abundant organism collected in entrainment samples whereas *Penaeus* spp. was the most abundant organism collected in larval impingement samples. The total mean density of organisms collected in entrainment samples increased approximately 73% from that collected in 1997. The total number of larval organisms collected in impingement samples also increased by 70% from the total number in 1997. Similar increases in the density and number of larval organisms entrained and impinged were likely the result of an overall increase in the abundance of larvae in the lower estuary.

Use of fine-mesh screens successfully reduced the number of organisms and the number of taxa entrained. The number of taxa entrained was reduced by 11 from a total of 51 taxa impinged. Depending upon taxa, entrainment of all organisms was reduced by approximately 33% with a range of 7% to 58% by using fine-mesh screens in 1998. Use of fine-mesh screens reduced enterainment of commercially important taxa by 44% with a range of 13% to 66% depending on taxa. As expected, variability in effectiveness of fine-mesh screens across months resulted in differences in species composition, seasonalities of larval recruitment, size of larvae, and number of coarse-mesh screens in operation. Based on survival estimates data, approximately 34% of all larval species impinged (excluding *Anchoa* spp. $\geq$ 13 mm) were returned alive to the estuary.

The 1998 juvenile and adult impingement catch was numerically dominated by white shrimp and bay anchovy. Prior to 1983, larger finfish such as Atlantic menhaden, spot, and croaker comprised the majority of the total weight impinged. Data collected during 1998 continued to show a shift towards impingement of smaller individuals for most of the selected species as a result of the construction of the diversion structure and the use of fine-mesh screens. This is important because it is the larger individuals which comprise the reproducing members of the population. Based on survival estimates, approximately 76% of the total number and 64% of the total weight of the impinged selected organisms, excluding bay anchovy, were returned alive to the estuary. Greater than 90% of the blue crabs and approximately 87% to 94% of the shrimp were returned alive to the estuary. These were the most valuable commercial species. Results of time-series analysis on 22 years of data indicated significant reductions in the impingement of larger fish and shellfish as a result of the diversion structure. Nine out of eleven selected taxa, including total organisms, exhibited significant decreases in impingement densities over the study period. The impingement density of juvenile and adult Atlantic menhaden exhibited the greatest decline.

Modifications made to the Brunswick Steam Electric Plant intake continued to be effective in reducing the number of organisms affected by the withdrawal of cooling water from the Cape Fear Estuary. The diversion structure excluded most large organisms. A substantial percentage of the larval, juvenile, and adult organisms impinged were returned alive to the estuary by using fine-mesh traveling screens and the fish return system.

Table 2.1 **Cumulative density (No./1000 m^3) and percent of total for fish, penaeid shrimp, and portunid megalops collected during entrainment sampling at the BSEP during 1997 and 1998 (based on ranking for 1998).**

	1997		1998	
Taxon	**Cumulative⁺ density**	**Percent**	**Cumulative⁺ density**	**Percent**
Gobiosoma spp.	783	18.5	2,053	28.2
Croaker	327	7.7	1,259	17.3
Spot	385	9.1	723	9.9
Penaeus spp.	465	11.0	661	9.1
Anchoa spp. (≥ 13 mm)	512	12.1	469	6.4
Portunid megalops	586	13.9	440	6.0
Weakfish	33	0.8	378	5.2
Anchoa spp. (<13 mm)	215	5.1	369	5.1
Gobionellus spp.	38	0.9	289	4.0
Silversides	248	5.9	137	1.9
Other taxa	634	15.0	512	7.0
Total¶	**4,226**	**100.0**	**7,290**	**100.0**

⁺ Cumulative density is the sum of the twelve sampling-day mean densities.

¶ Total may vary from summation due to rounding of individual taxon.

Table 2.2 Total number of selected taxa estimated by larval impingement sampling at the BSEP during 1998, ranked by percent.

Taxon	Total number+	Percent
Penaeus spp.	3.5×10^6	20.6
Croaker	3.5×10^6	20.4
Spot	3.0×10^6	17.8
Anchoa spp. (≥13 mm)	2.0×10^6	11.8
Portunid megalops	1.4×10^6	8.0
Gobiosoma spp.	1.0×10^6	6.0
Gobionellus spp.	7.3×10^5	4.3
Atlantic menhaden	6.3×10^5	3.7
Pinfish	3.2×10^5	1.9
Weakfish	2.2×10^5	1.3
Other taxa	7.1×10^5	4.2
Total¶	$\mathbf{1.7 \times 10^7}$	**100.0**

+Total number is a sum of the twelve sampling-day totals.

¶Total may vary from summation due to rounding of individual taxon.

Table 2.3 Total number, total weight, and percent of total of the ten most abundant juvenile and adult organisms collected in the BSEP impingement samples during 1998.

Taxon	Number+	Percent¶	Weight (kg)+	Percent¶
White shrimp	122,281	56.3	384.7	44.5
Bay anchovy	61,678	28.4	60.6	7.0
Spot	7,326	3.4	88.7	10.3
Atlantic menhaden	7,081	3.3	88.6	10.2
Lesser blue crab	2,876	1.3	9.0	1.0
Blue crab	2,629	1.2	93.6	10.8
Brown shrimp	1,838	0.9	14.2	1.6
Star drum	1,446	0.7	5.9	0.7
Croaker	1,354	0.6	31.0	3.6
Blackcheek tonguefish	1,228	0.6	5.0	0.6
Other taxa	7,561	3.5	83.3	9.6
Total	**217,298**		**864.6**	

+Numbers and weights are sums of the twelve sampling day totals.

¶Percentages may not add up due to rounding.

Table 2.4 Entrainment densities (mean no./1000 m^3 per sampling day) of selected taxa$^+$ at the BSEP during 1998.

Taxa	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Portunid Megalops	0	0	0	0	0	34.4	134.9	212.8	15.9	5.7	23.9	12.2
Penaeus spp.	0	0	3.1	8.4	5.6	76.5	348.3	120.2	8.0	53.4	5.9	31.2
Croaker	606.8	38.8	216.5	117.1	124.8	0	0	0	0	2.8	17.4	134.8
Anchoa spp. (< 13 mm)	0	0	0	0	174.3	31.6	27.4	127.1	8.6	0	0	0
Anchoa spp. (≥ 13 mm)	60.8	3.4	34.3	26.3	38.8	121.2	45.8	13.7	179.5	5.6	5.7	0
Spot	94.0	154.3	423.0	44.2	4.8	0	0	0	0	0	0	3.1
Gobionellus spp.	27.6	13.1	37.6	20.0	8.5	40.2	92.4	5.9	0	33.9	0	9.5
Gobiosoma spp.	0	0	0	0	111.7	681.0	942.1	285.3	31.5	1.40	0	0
Silversides	0	0	0	128.5	5.3	0	0	0	0	0	0	0
Hardback shrimp	0	0	0	0	0	66.1	17.9	9.3	0	0	0	0
Swimming crabs	0	0	0	0	0	2.9	8.6	0	8.3	0	0	0
Pinfish	17.6	16.7	9.4	43.2	0	0	0	0	0	0	0	0
Atlantic menhaden	0	0	12.5	24.2	0	0	0	0	0	0	0	0
Weakfish	0	0	0	0	348.8	17.3	0	0	11.6	0	0	0
Total Organisms	**809.9**	**252.5**	**727.1**	**394.5**	**911.2**	**1,111**	**1,658**	**822.8**	**272.0**	**102.7**	**52.9**	**193.9**

$^+$Selected taxa comprised ≥ 1% of the total sampled in either entrainment or larval impingement.

Table 2.5 Entrainment rates (million per sampling day) of selected taxa⁺ at the BSEP during 1998.

Taxa	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Portunid Megalops	0	0	0	0	0	0.185	0.753	1.213	0.086	0.030	0.128	0.055
Penaeus spp.	0	0	0.014	0.045	0.015	0.412	1.944	0.685	0.043	0.287	0.032	0.141
Croaker	2.738	0.173	0.991	0.631	0.336	0.015	0	0	0	0.015	0.094	0.608
Anchoa spp. (< 13 mm)	0	0	0	0	0.469	0.170	0.153	0.725	0.046	0	0	0
Anchoa spp. (≥ 13 mm)	0.274	0.015	0.155	0.142	0.104	0.652	0.256	0.078	0.966	0.030	0.031	0
Spot	0.425	0.696	1.909	0.238	0.013	0	0	0	0	0	0	0.014
Gobionellus spp.	0.124	0.059	0.169	0.108	0.023	0.023	0.516	0.034	0	0.183	0	0.043
Gobiosoma spp.	0	0	0	0	0.301	3.666	5.259	1.627	0.170	0.008	0	0
Silversides	0	0	0	0.692	0.014	0.014	0	0	0	0	0	0
Hardback shrimp	0	0	0	0	0	0.356	0.100	0.053	0	0	0	0
Swimming crabs	0	0	0	0	0	0.016	0.048	0	0.045	0.006	0	0
Pinfish	0.080	0.080	0.042	0.233	0	0	0	0	0	0	0	0.028
Atlantic menhaden	0	0	0.056	0.146	0	0	0	0	0	0	0	0
Weakfish	0	0	0	0	0.939	0.093	0	0	0.063	0	0	0
Total Organisms	**3.753**	**1.049**	**3.379**	**2.248**	**2.455**	**5.982**	**9.255**	**4.691**	**1.464**	**0.553**	**0.285**	**0.875**
Volume (10^6 m^3)	**4.512**	**4.512**	**4.512**	**5.383**	**2.692**	**5.383**	**5.582**	**5.701**	**5.383**	**5.383**	**5.383**	**4.512**

⁺Selected taxa comprised ≥ 1% of the total sampled in either entrainment or larval impingement.

Table 2.6 Total number (million per sampling day) of selected taxa+ estimated by monthly samples of larval impingement at the BSEP during 1998.

Taxa	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Portunid megalops	0.008	0	0.007	0.182	0.003	0.209	0.421	0.212	.037	0.107	0.126	0.057
Penaeus spp.	0.003	0	0.147	0.341	0.004	1.181	1.201	0.077	0.007	0.452	0.050	0.061
Croaker	2.024	0.172	0.432	0.623	0.080	0	0	0	< 0.001	0.025	0.049	0.012
Anchoa spp. (< 13 mm)	0	0	0	0	0.033	0.019	0.025	0.004	0.001	0	0	0
Anchoa spp. (≥ 13 mm)	0.207	0.050	0.158	0.139	0.314	1.151	0.027	0.002	0.111	0.010	0.048	0.003
Spot	0.186	1.116	1.466	0.260	0.029	0	0	0	0	0	0	0.010
Gobionellus spp.	0.102	0.023	0.131	0.192	0.004	0.040	0.108	0.010	0	0	0	0
Gobiosoma spp.	1.102	<0.001	0	0	0.008	0.693	0.297	0.028	0.005	< 0.001	0	0
Silversides	0	0	0	0	0.001	0	0	<0.001	0	0	0	0
Hardback shrimp	0	0	0	0	0	<0.001	0.004	0	0	0.02	0	0
Swimming crabs	0	0	0	0.048	0	0.002	<0.001	0	0	0	0	0
Pinfish	0.082	0.041	0.037	0.133	0	0	0	0	0	0	<0.001	0.024
Atlantic menhaden	0.002	0.015	0.137	0.478	<0.001	0	0	0	0	0	0	0.001
Weakfish	0	0	0	0	0.555	0.032	0	<0.001	0.007	0	0	0
Total organisms	**2.650**	**1.475**	**2.574**	**2.513**	**1.125**	**3.509**	**2.154**	**0.349**	**0.177**	**0.714**	**0.279**	**0.290**

+Selected taxa comprised ≥ 1% of the total sampled in either entrainment or larval impingement.

Table 2.7 **Juvenile and adult impingement densities (No./million m^3 of water entrained during each 24-hour sampling period) for selected species+ and the number of damaged diversion screens per month at the BSEP during 1998.**

Month	Bay anchovy	Atlantic menhaden	Spot	Croaker	White shrimp	Brown shrimp	Pink shrimp	Blue crab	Damaged screens
Jan	4,563	415	781	99	63	0	1	10	5
Feb	2,133	427	397	4	0	0	0	14	8
Mar	1,610	262	181	19	13	0	1	133	3
Apr	2,702	185	15	50	17	0	0	128	6
May	117	43	17	67	<1	0	0	50	10
Jun	174	56	95	37	4	249	0	180	40
Jul	6	9	17	<1	190	68	0	159	21
Aug	23	1	8	1	421	205	3	617	1
Sep	218	116	72	25	20,708	0	39	330	30
Oct	132	1	5	2	75	4	11	19	14
Nov	1,123	2	1	0	1,205	0	4	15	7
Dec	71	0	1	0	1	<1	1	4	0

+Selected species, with the exception of bay anchovy are commercially and recreationally important species which accounted for greater than 1% of the total catch by number or weight.

Table 2.8 **Modal lengths (mm) for selected[+] juvenile and adult impingement species[¶] collected by month at the BSEP during 1998.**

Month	Atlantic menhaden	Spot	Croaker	White shrimp	Brown shrimp	Pink shrimp
Jan	100	70	120	90	NC[§]	ID
Feb	90	70	ID[£]	NC	NC	NC
Mar	95	100	120	ID	NC	ID
Apr	85	105	130	110	NC	NC
May	90	ID	70	ID	NC	NC
Jun	45	45	45	ID	95	NC
Jul	ID	50	ID	65	115	NC
Aug	ID	ID	ID	80	115	ID
Sep	70	75,80	ID	75	NC	55
Oct	ID	ID	ID	120	ID	50
Nov	ID	ID	NC	90	NC	ID
Dec	NC	ID	NC	ID	ID	ID

[+]Selected species are commercially and recreationally important species which accounted for greater than 1% of the total catch by number or weight.

[¶]Fish ≥ 41 mm and crabs ≥ 25 mm.

[§]NC= None collected.

[£]ID = Insufficient number collected (< 10).

Table 2.9 Time-series analysis of BSEP juvenile and adult impingement data indicating trends in density from January 1977 through December 1998.

Taxon	Trend+	Slope	R^2
Atlantic menhaden	—***	— 0.00046	0.97
Weakfish	—***	— 0.00027	0.97
Blue crabs	—***	— 0.00025	0.96
Spot	—***	— 0.00023	0.97
Croaker	—***	— 0.00025	0.96
Southern flounder	—***	— 0.00017	0.96
Pink shrimp	—***	— 0.00017	0.96
Bay anchovy	— ***	— 0.00007	0.98
Brown shrimp	— **	— 0.00005	0.97
White shrimp	+***	0.00030	0.98
Total organisms	**—*** **	**— 0.00016**	**0.96**

+Trends are explained with the following notation:

NS = $P > 0.05$
* = $0.01 < P \leq 0.05$
** = $0.001 < P \leq 0.01$
*** = $P \leq 0.001$
+ = Increasing trend
— = Decreasing trend

R^2 = Amount of variation explained by the dependent variable in the time-series model.

Table 2.10 Percent effectiveness of fine-mesh screens in reducing the number of selected taxa entrained per sampling day at the BSEP during 1998.

Taxa	Month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Portunid megalops	100	100	100	100	100	53	36	15	30	78	50	51	**36**
Penaeus spp.	100	NP[+]	91	88	20	74	38	10	14	61	61	30	**49**
Croaker	43	50	30	50	18	0	NP	NP	100	63	34	17	**39**
Anchoa spp. (< 13 mm)	NP	NP	NP	NP	7	10	14	1	2	NP	NP	NP	**22**
Anchoa spp. (≥ 13 mm)	43	77	51	50	75	64	10	3	10	25	61	100	**44**
Spot	30	62	43	52	69	NP	NP	NP	NP	NP	NP	41	**48**
Gobionellus spp.	45	28	44	64	14	16	17	24	100	37	100	9	**33**
Gobiosoma spp.	100	100	NP	NP	3	16	5	2	3	5	NP	NP	**9**
Silversides	NP	NP	NP	0	4	NP	NP	100	NP	NP	NP	NP	**< 1**
Hardback shrimp	NP	NP	NP	NP	NP	< 1	4	0	NP	100	NP	NP	**3**
Swimming crabs	NP	NP	NP	100	NP	12	1	NP	0	NP	NP	NP	**32**
Pinfish	51	35	47	36	NP	NP	NP	NP	NP	NP	100	100	**48**
Atlantic menhaden	100	100	71	77	100	NP	NP	NP	NP	NP	NP	NP	**76**
Weakfish	NP	NP	NP	NP	37	26	NP	100	9	NP	NP	NP	**35**
Total Organisms	**41**	**58**	**43**	**53**	**31**	**37**	**19**	**7**	**11**	**56**	**50**	**25**	**33**

[+]NP = Not Present.

Table 2.11 Estimated number and percent survival of selected larval organisms collected during impingement sampling at the BSEP during 1998.

Taxon	Number collected	Percent survival+ slow	Percent survival fast
Penaeus spp.	3.5×10^6	80.3	90.3
Croaker	3.5×10^6	14.4	33.7
Spot	3.0×10^6	9.0	29.4
Anchoa spp. (≥ 13 mm)	2.0×10^6	0.3	0.7
Portunid megalops	1.4×10^6	86.3	87.0
Gobionellus spp.	7.3×10^5	-	15.4
Atlantic menhaden	3.2×10^5	0.0	3.2
Weakfish	2.2×10^5	-	12.6
Hardback shrimp	6.8×10^3	48.4	78.8
Total	**1.4×10^7**		
Percent survival¶		**33.9**	

+Reference: CP&L 1988 (slow and fast screen rotation).

¶Survival estimate is for all species excluding *Anchoa* spp. (≥ 13 mm) and is calculated using results for fast-screen rotation speed during June through August and November and slow-screen rotation speed the remainder of the year.

Table 2.12 Estimated number, weight (kg), and percent survival of selected juvenile and adult organisms collected during impingement sampling at the BSEP during 1998.

Taxon	Number collected	Weight collected	Percent survival+ slow	Percent survival fast
Shrimp (pink and white)	122,595	386.8	86.5	93.7
Bay anchovy	61,678	60.6	1.1	4.9
Spot	7,326	88.7	57.1	60.4
Atlantic menhaden	7,081	88.6	-	15.6
Blue crabs	5,505	102.6	92.1	96.2
Brown shrimp	1,838	14.2	90.7	90.4
Croaker	1,354	31.0	53.1	45.1
Blackcheek tonguefish	1,228	5.0	-	83.1
Weakfish	476	2.0	-	35.0
Paralichthys spp.	180	9.9	-	71.1
Striped mullet	8	0.8	-	92.0
Total	**209,269**	**790.2**		
Percent survival¶ (all species)	**55.0% by number**	**59.8% by weight**		
Percent survival (all species excluding bay anchovy)	**76.2% by number**	**64.2% by weight**		

+Reference: CP&L 1988 (Slow and fast screen rotation).

¶Survival estimate is for all species excluding *Anchoa* spp. ($\geq$ 13 mm) and is calculated using results for fast-screen rotation speed during June through August and November and slow-screen rotation speed the remainder of the year.

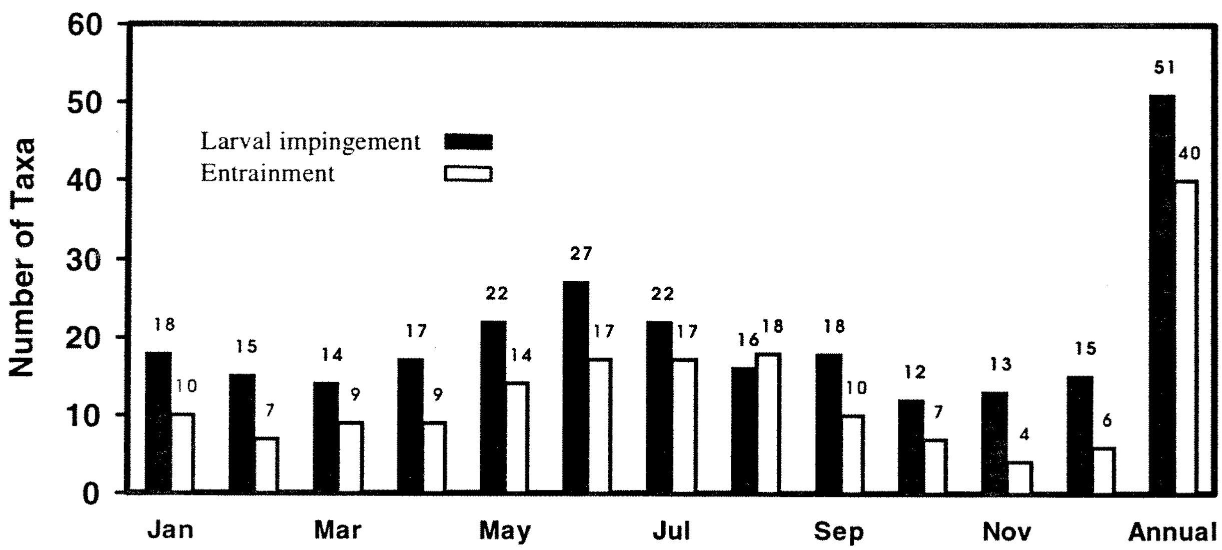

Figure 2.1 Number of taxa collected in entrainment and larval impingement samples at the BSEP during 1998.

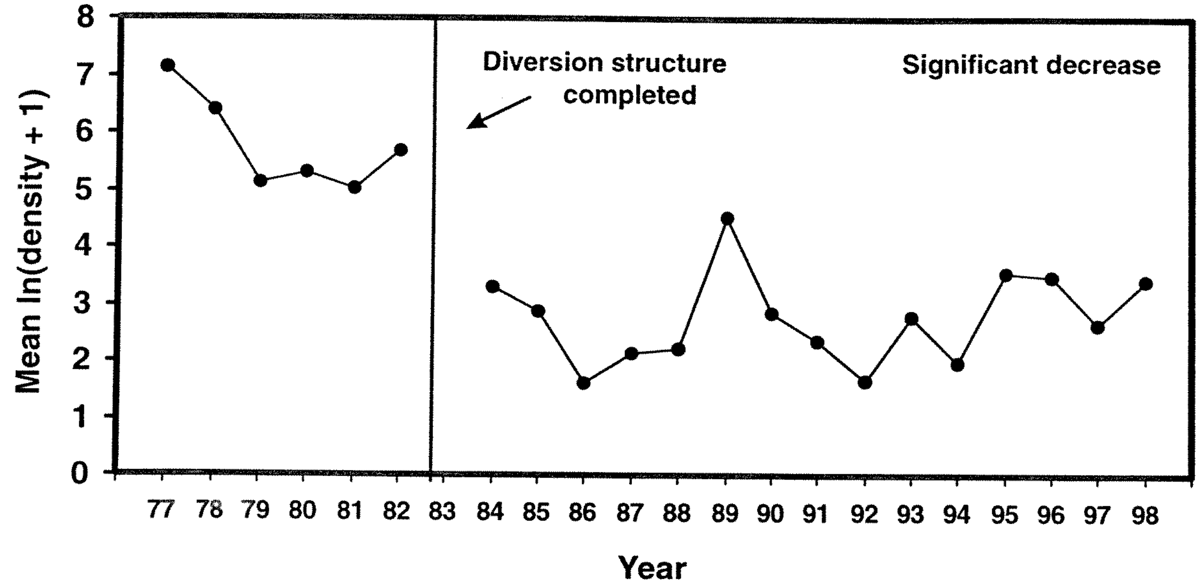

Figure 2.2 Time-series analysis of juvenile and adult Atlantic menhaden data collected during impingement sampling at the BSEP from 1977 through 1998.

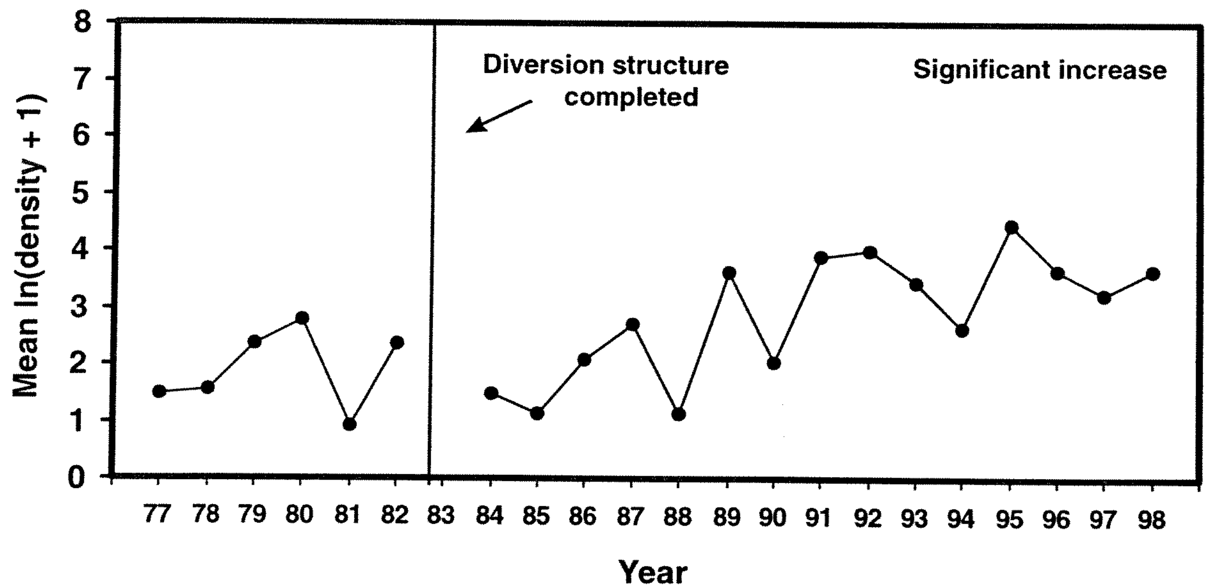

Figure 2.3 Time-series analysis of juvenile and adult white shrimp data collected during impingement sampling at the BSEP from 1977 through 1998.

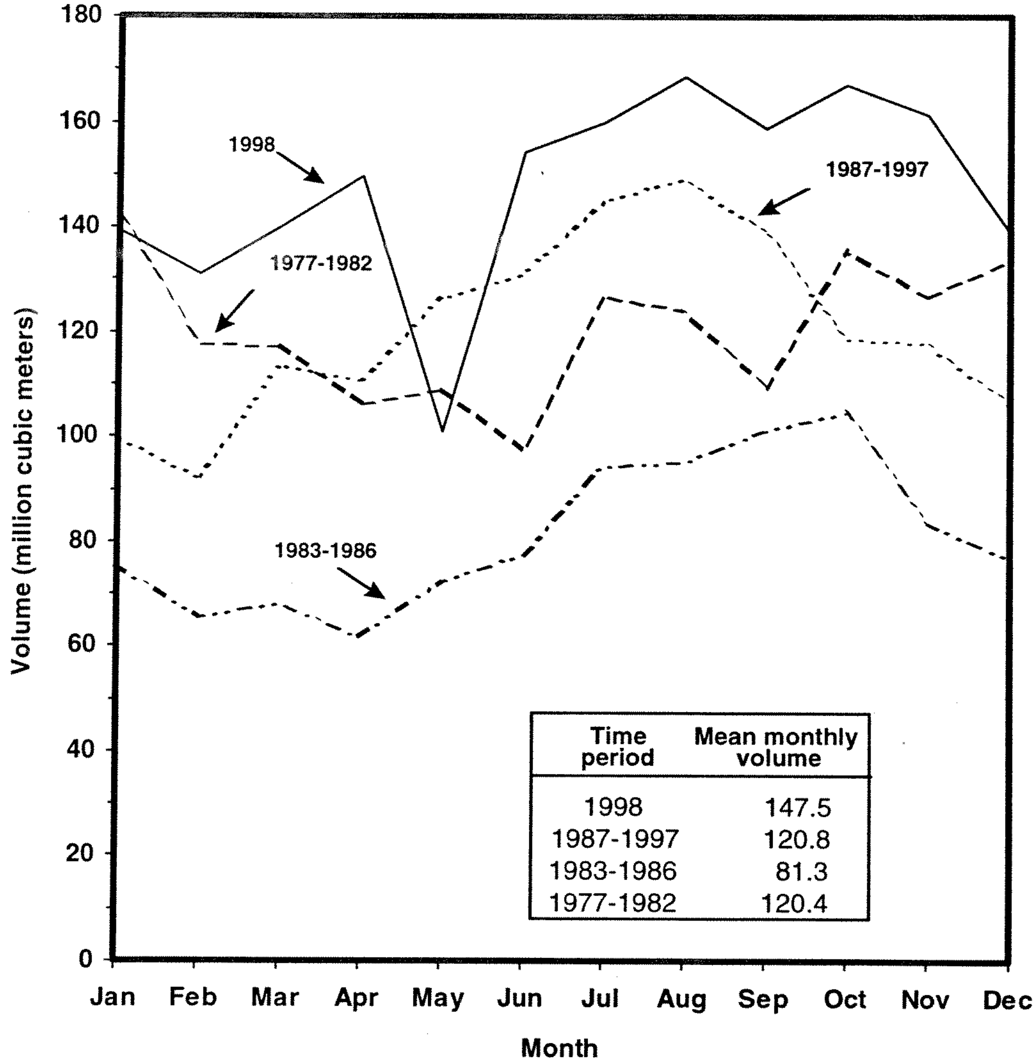

Figure 2.4 Monthly flow (million cubic meters) of water pumped at the BSEP from 1977 through 1998.

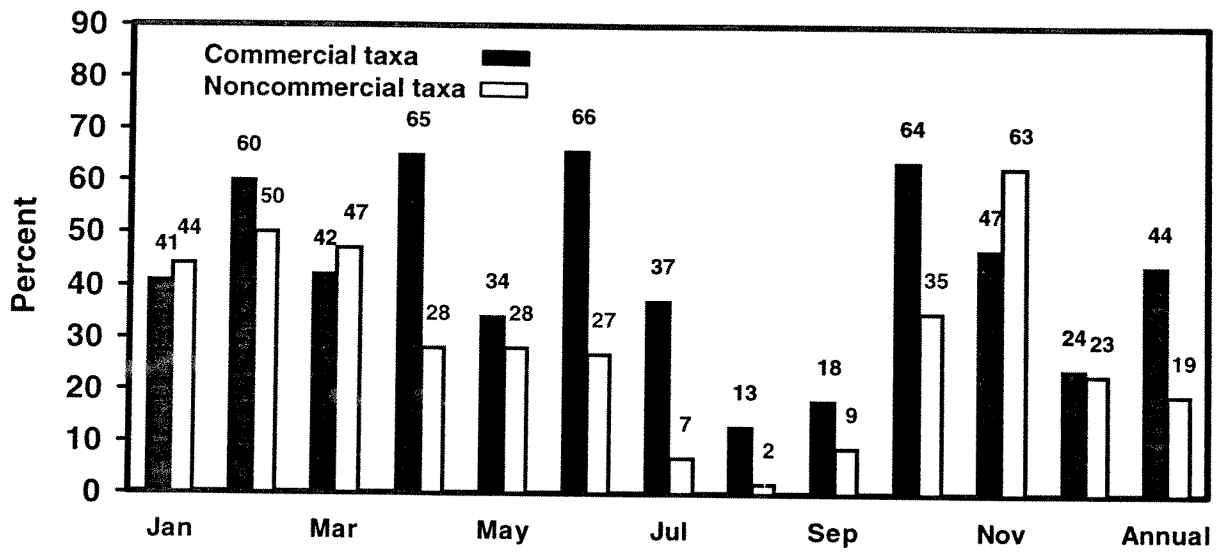

Figure 2.5 Percent effectiveness of fine-mesh screens in reducing the number of commercial and noncommercial taxa entrained per sampling day at the BSEP during 1998.

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